X. *Account of an improved Thermometer. By Mr.* James Six; *comunicated by the Rev. Mr.* Wollaſton, *F. R. S.*

Read February 28, 1782.

ATTEMPTING ſome time ago to aſcertain the greateſt degree of heat and cold that happened in the atmoſphere each day and night, or during the courſe of twenty-four hours, I experienced the inconvenience which attends thermometers commonly made uſe of for that purpoſe; the neceſſity I mean of the obſerver's eye being on the inſtrument the very inſtant the mercury ſtands at the higheſt or loweſt degree: for, ſince the time when that may happen is utterly uncertain, if it be not immediately noticed, it can never after be known. The ſultry heat of the ſummer's days, and freezing cold of the winter's nights, which is commonly moſt ſevere at a late unſeaſonable hour, render it very unpleaſant to be abroad in the open air, although it is abſolutely neceſſary for the thermometer to be placed in ſuch a ſituation. Ingenious men of our own country, as well as foreigners, have, it ſeems, long ago endeavoured to remedy this inconvenience; and ſeveral thermometers of different conſtructions have been invented for that purpoſe. VAN SWINDEN deſcribes one which he ſays was the firſt of the kind, made on a plan communicated by Mr. BERNOULLI to Mr. LEIBNITZ. Mr. KRAFT, he alſo tells us, made one nearly like it*. A deſcription of thoſe by Lord

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* Diſſ. ſur la Comparaiſon du Therm. par VAN SWINDEN, p. 253—255.

CHARLES CAVENDISH and Mr. FITZGERALD may be ſeen in the Philoſophical Tranſactions *. Though much ingenuity appears in the invention of thoſe curious inſtruments, I could not forbear thinking, that a thermometer might be conſtructed more conveniently to anſwer the purpoſe, and ſhew accurately the greateſt degree of heat and cold which happened in the obſerver's abſence. I therefore attempted to make one: with what ſucceſs I ſubmit to your better judgement, and proceed to give a deſcription of the inſtrument. Fig. 1. *ab* is a tube of thin glaſs, about ſixteen inches long, and five ſixteenths of an inch in diameter; *cdefgh* a ſmaller tube with the inner diameter, about one fortieth, joined to the larger at the upper end *b*, and bent down, firſt on the left ſide, and then, after deſcending two inches below *ab*, upwards again on the right, in the ſeveral directions *cde*, *fgh*, parallel to, and one inch diſtant from it. On the end of the ſame tube at *h*, the inner diameter is enlarged to half an inch from *h* to *i*, which is two inches in length. This glaſs is filled with highly rectified ſpirits of wine to within half an inch of the end *i*, excepting that part of the ſmall tube from *d* to *g*, which is filled with mercury. From a view of the inſtrument in this ſtate, it will readily be conceived, that when the ſpirit in the large tube, which is the bulb of the thermometer, is expanded by heat, the mercury in the ſmall tube on the left ſide will be preſſed down, and conſequently cauſe that on the right ſide to riſe; on the contrary, when the ſpirit is condenſed by cold, the reverſe will happen, the mercury on the left ſide will riſe as that on the right ſide deſcends. The ſcale, therefore, which is FAHRENHEIT's, beginning with *o* at the top of the left ſide, has the degrees numbered downwards, while that at the right ſide, beginning with *o* at the bottom, aſcends. The diviſions are aſcertained by placing this thermometer with a good ſtandard mercurial one in water gradually heating or cooling, and marking the diviſions of the new ſcale at every 5°*. Thus far our thermometer reſembles in ſome reſpects thoſe of Mr. BERNOULLI and Lord CHARLES CAVENDISH; but the method of ſhewing how high the mercury had riſen in the obſerver's abſence, the eſſential property of an inſtrument of this kind, is wholly different from theirs, and effected in the following manner. Within the ſmall tube of the thermometer, above the ſurface of the mercury on either ſide, immerſed in the ſpirit of wine, is placed a ſmall index, ſo fitted as to paſs up and down as occaſion may require: that ſurface of the mercury which riſes carries up the index with it, which index does not return with the mercury when it deſcends; but, by remaining fixed, ſhews diſtinctly, and very accurately, how high the mercury had riſen, and conſequently what degree of heat or cold had happened. Fig. 2. repreſents one of theſe indexes drawn larger than the real ones, to render it more diſtinct. *a* is a ſmall glaſs tube, three quarters of an inch long, hermetically ſealed at each end, incloſing a piece of ſteel wire, nearly of the ſame length; at each end *c d* is fixed a ſhort piece of a tube of black glaſs, of ſuch a diameter as to paſs freely up and down within the ſmall tube of the thermometer. The lower end, floating on the ſurface of the mercury, is carried up with it when it riſes, while the piece at the upper end, being of the ſame diameter, keeps the body of the index parallel to the ſides of the thermometrical tube. From the upper end of the body of the index at *c* is drawn a ſpring of glaſs to the

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* Phil. Tranſ. vol. L. p. 501. and vol. LI. p. 820.

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* The diviſions below the freezing point are taken by means of a mixture of ſea ſalt and ice, as deſcribed by NOLLET, DE LUC, and others.

the fineneſs of a hair, about five ſevenths of an inch in length, which, being ſet a little oblique, preſſes lightly againſt the inner ſurface of the tube, and prevents the index from following the mercury when it deſcends, or being moved by the ſpirit paſſing up or down, or by any ſudden motion given to the inſtrument by the hand or otherwiſe; but at the ſame time the preſſure is ſo adjuſted as to permit this index to be readily carried up by the ſurface of the riſing mercury, and downwards whenever the inſtrument is be rectified for obſervation. To prevent the ſpirit from evaporating, the tube at the end *i* is cloſely ſealed *. Fig. 3. repreſents the thermometer on its frame; the plates on which the ſcale is graved on either ſide are made to ſlide out, and the frame is open to the back, behind the large tube, which does not touch it, except at each end. The cap *a*, and the baſe *b*, are made to fix on with ſcrews, and only cover the turning of the ſmall tube. By a ſcrew at the bottom of the frame, it may be made faſt to the wall againſt which it is to hang without doors, to prevent its being ſhaken by violent winds. Towards evening I uſually viſit my thermometer, and ſee at one view, by the index on the left ſide, the cold of the preceding night; and by that on the right, the heat of the day. Theſe I minute down, and then apply a ſmall magnet to that part of the tube againſt which the indexes reſt, and move each of them down to the ſurface of the mercury: thus, without heating, cooling, ſeparating, or at all diſturbing the mercury, or moving the inſtrument, may this thermometer, without a touch, be immediately rectified for another obſervation. When I wiſh to put the thermometer out of my hand, without hanging it up, I have a ſtand to place it on; for if the mercury preſſes againſt the index, while the inſtrument lies in an horizontal poſition, it is in danger of paſſing by it, which is avoided by keeping the thermometer in a poſition nearly vertical. To prevent the mercury ſhifting its place in the ſpirits within the tube (which I apprehended it might do on account of the ſuperiority of its ſpecific gravity, eſpecially when kept for a conſiderable time, very high on one ſide, and low on the other), I made that part of the ſmall tube from *e* to *f* with the inner diameter exceeding ſmall; and found, upon trial, that after the ſummer's heat had kept the mercury for a long time high on one ſide, the winter's cold brought it again as accurately to the freezing point on the other as at firſt*. This thermometer may be made a mercurial one by inverting the glaſs, and filling with mercury that part which in the firſt is filled with ſpirits, and with ſpirits that part of the ſmall tube from *d* to *g* which in the former is filled with mercury; the indexes in either caſe may be the ſame, and will be carried up in the ſame manner upon the ſurface of the mercury; but the end of the tube at *i*, inſtead of being ſealed, muſt then be left open, and ſtand inverted in a bulb, or ſmall ciſtern of mercury, into which the external air has free acceſs. The diameter of the tube *a b* ſhould be conſiderably increaſed if the degrees on the ſcale are required to be as wide as thoſe in the ſpirit thermometers. It is indeed better in this caſe to have a double rather than a larger ſingle tube; but finding the weight of ſo great a quantity of mercury in a thin glaſs tube attended with many diſadvantages, and the motion of the fluids in the ſpirit-ones perfectly agreeing with, and being as readily excited by change of heat and cold, as in the mercurial thermometers, I preferred the former as much more commodious. A perſon cannot approach near to the thermometer firſt deſcribed when the air is very cold (eſpecially with a light which by night is neceſſary) without cauſing the ſpirits preſently to expand, and conſequently the mercury on the left ſide immediately to deſcend. This ſenſibility is here attended with every advantage, without the inconvenience to which common thermometers in this caſe are liable *; for the index will accurately ſhew the greateſt height to which the mercury had riſen, although, before the exact degree can well be diſtinguiſhed, it will appear ſeparated from the index, and deſcending apace. As the ſcale is ſixteen inches long, and divided into 100° only, which are more than ſufficient for the temperature of the air, they are large enough to be ſub-divided at pleaſure. The indexes, though of a tender and delicate nature, when once placed in the tube, are not liable to ſuffer any alteration by time or accident; and the thermometer may be expoſed to rain at all times, without ſuffering the leaſt injury in any reſpect.

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* When this tube is cloſed (not hermetically, but only ſo as to prevent the ſpirits evaporating) the thermometer muſt be brought to the greateſt heat it is likely at any time after to ſuſtain; and though no more air is incloſed than what remains at that time above the ſpirits, yet that will, by its elaſticity preſſing on the fluid, anſwer every purpoſe as well as if the external air was freely admitted.

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* With a thermometer of this ſort I obſerved the greateſt heat and cold that happened every day and night throughout the year 1781.

In conſtructing the thermometer before mentioned, I at firſt hit on a plan by which the ſame end was obtained by a different

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* The moſt ſenſible mercurial thermometers commonly have the column of mercury as well as the degrees very ſmall, and a perſon aſſiſted with a light can hardly view them near enough, when the weather is very cold, without cauſing the mercury to riſe before the degrees where it ſtood can be well aſcertained.

Freezing fogs alſo, which with us uſually attend the greateſt degrees of cold, by covering the glaſs with froſt, render the mercury inviſible, and cannot well be mercury removed without cauſing the to riſe, or at leaſt render the obſervation doubtful, which at ſuch a time is very diſagreeable; for, in proportion to the extraordinary degree of cold, ſo is our curioſity likely to be excited.

ferent method; and though, in ſome reſpects, and for ſome purpoſes, it may not be ſo proper as that already deſcribed, yet, for ſome others, it may be found uſeful, and therefore I ſhall briefly deſcribe it. The glaſs of this inſtrument is in all reſpects the ſame as in the former, excepting that the diameters of the tubes are ſomething larger. It is likewiſe filled with ſpirits of wine and mercury, in the ſame manner; but the indexes are different, being only a ſmall tube of black glaſs, about five-ſevenths of an inch in length, hermetically ſealed at each end, containing a piece of ſteel wire. An index of this ſort is placed in the thermometer on either ſide, which, having no ſpring to ſupport them, ſink down in the ſpirits, and reſt upon the mercury. Whenever the mercury deſcends, the index will follow it; but when it riſes, the index will not riſe with it, and by remaining at the place to which the mercury had deſcended, will ſhew the greateſt degree of heat or cold which had happened. In this manner do theſe indexes anſwer the ſame purpoſe, though they move directly contrary to the others in the other thermometer; but this inſtrument is not ſo eaſily rectified as the former, for the moſt powerful magnet will not bring the index up again while the mercury above preſſes againſt them; and although it is poſſible to remove the mercury, and by that means ſet the index at liberty, yet inconveniences will be incurred from which the other is entirely free.

In ſome caſes it may be found expedient, inſtead of the double thermometer firſt deſcribed, to make two ſingle ones; one to ſhew the greateſt degree of heat only, and the other the cold, each having its proper index (ſee fig. 4. and 5.). The firſt has the ſmall tube bent down on the left ſide, and the lower end immerſed in a bulb or ſmall ciſtern of mercury, to which the external air has free acceſs; the other has the ſmall tube turned up on the right ſide, with ſome mercury let down to the bottom, and the upper end cloſely ſealed, as in the double inſtrument. Making a ſtandard mercurial thermometer, by which the ſcale of the ſpirit one was to be divided, I endeavoured to obtain as wide degrees as poſſible, that the motion of the mercury might thereby be rendered more conſpicuous, and the height of it aſcertained with greater preciſion. It is true, the larger the degrees, the larger in ſome meaſure muſt be the bulb, and therefore the fluid contained in it not likely to be ſo ſoon affected by any change of heat or cold in the atmoſphere as in a ſmaller. But as this thermometer was principally to be uſed immerſed in a large quantity of water, gradually heating or cooling, little or no diſadvantage could ariſe from making the bulb ſomewhat larger than thoſe commonly made uſe of in the air. Not being able, however, to procure glaſs tubes ſo long as I had occaſion for, whoſe inner diameters were perfectly equal, I took the following method to adjuſt the diviſions on the ſcale to the inequality of the tubes. Chooſing a tube of a length ſuitable to my purpoſe, with a proper bulb at the end, I put into it a ſmall quantity of mercury * ſufficient to form a column about one inch in length. Drawing then on a board the three lines *aa*, *bb*, *cc*, fig. 6. I placed the glaſs tube on the line *aa*, and while the mercury remained at reſt at the end of the tube, near the bulb, I made two pencil marks on the line *aa*, one at *d*, and the other at *e*, perfectly coinciding with the two ends of the column of mercury: then cauſing the mercury to move ſlowly on farther from the bulb, till that end of the column which was firſt at *d* coincided with the mark at *e*, and letting it reſt again, I made another mark at *f*; after which, cauſing the mercury to move on as before, and continuing to mark its length at every part of the tube till it reached the end fartheſt from the bulb; by theſe means I obtained the ſeveral intermediate points on the line *aa*. Through theſe ſeveral points I drew dotted lines parallel to each other, and at right angles with the line *aa* to the line *bb*. Taking now, with a pair of compaſſes, the wideſt intervals between any of the dotted parallels, which in this caſe is from *d* to *e*, I inſerted that diſtance ſucceſſively between the ſeveral parallels, beginning at the loweſt pair, as from *d* to *e*, from *e* to *f*, from *f* to *g*, and ſo on to *h*, as exhibited in the figure; and the aggregate of theſe lines may be conſidered as one continued line, without any error of conſequence in this matter. Having now the thermometer completely filled with mercury, the air expelled, the point of the ſcale at 102°, and the freezing point properly taken * and marked upon the tube, which was now hermetically ſealed, I again applied the tube to the line *aa*, and marked on that line the point of 102° and the freezing point. Through thoſe points I drew the lines *ii*, *kk*, and divided that part of the compound line *dh* included between *ii* and *kk* into 14 equal parts, beginning at *o*, the point where *ii* cuts the line *dh*, continuing afterward ſix diviſions now on that line below *kk*, making in all 20 equal diviſions. If now lines be drawn through each of the dividing points, from *o* to 20 to the line *cc*, at right angles with the ſame, they will give on the line *cc* the true thermometrical ſcale to every 5° from 2 to 102, properly adjuſted to the inequality of the tube *, which in this caſe is nearly of the ſame diameter at each end, but ſmaller towards the middle. Tubes may indeed be found of ſome conſiderable length with leſs inequality than what this ſcale exhibits; but the error is here enlarged, to render the method of correcting it more conſpicuous.

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* To put in a ſmall quantity of mercury, and meaſure its length at different parts of the tube, as deſcribed by Abbé NOLLET, vol. IV. p. 370. Lecons Phyſique, is a very excellent method to diſcover the error; but in what manner readily to adjuſt the ſcale, ſo as to avoid any inaccuracy from ſuch inequality (which in tubes of the length I had occaſion for ſeemed to me unavoidable) was a matter concerning which I could meet with no information.

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* The freezing point, marked on the tube of this thermometer, is immediately taken by means of grated ice; but the point of 100° by a ſtandard mercurial thermometer, the upper point of the ſcale of which was properly taken by boiling water, and the lower one by grated ice; but it is more commodious in the firſt to have the tube no longer than the air ſcale, eſpecially as the degrees are pretty wide. The method of adjuſting the ſcale to the inequality of the tube remains the ſame, let the given points be at any diſtance, or the diviſions increaſed to any number.

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* Experimentally to prove this method I have made mercurial thermometers, whoſe ſcales from the freezing point to that of boiling heat were nearly three feet, and though the inequalities of the tubes were very conſiderable, varying in contrary directions to each other; yet when they were placed on the ſame frame, they perfectly agreed in a motion of the mercury in every part of their ſcales.